

Introduction to Structural Geology

(General review; Course focus)

Structural Geology

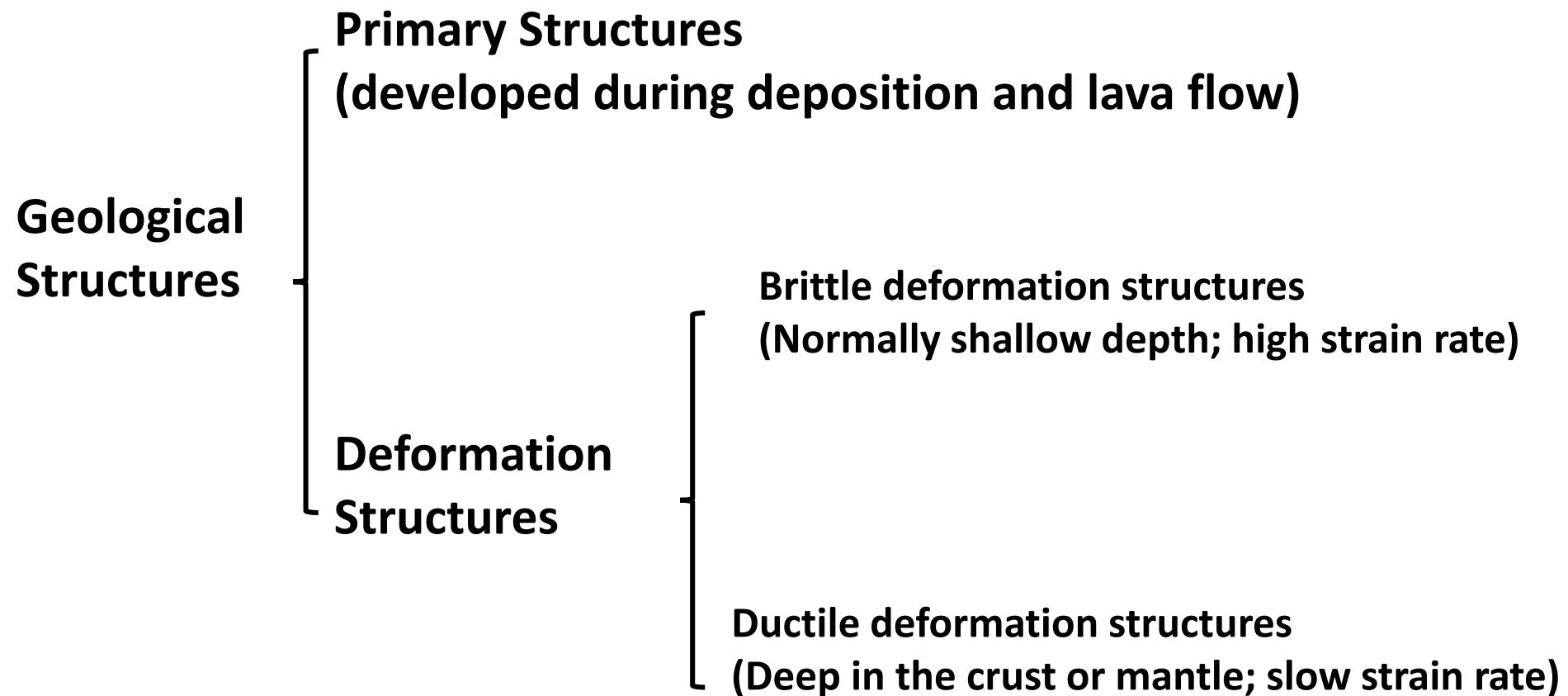
The study of geological structures in rocks.

Structures (geometry), Processes of forming structures (motion; kinematics), and Cause (mechanical behavior).

Outline

- Geological structures
- Purpose and 3 levels of study
 - Geometrical study
 - Kinematic study (motion; Kinematics)
 - Dynamic study (Cause; Mechanic behavior)
- Kinematic study based on geometry
- Structures in tectonic setting

Geological structures



Some Primary Structures



Sedimentary bedding

Horizontal;
Constant thickness at outcrop scale;
Same composition/grain size within one layer

Figure 5.7d

From a geology book

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Foreset bed

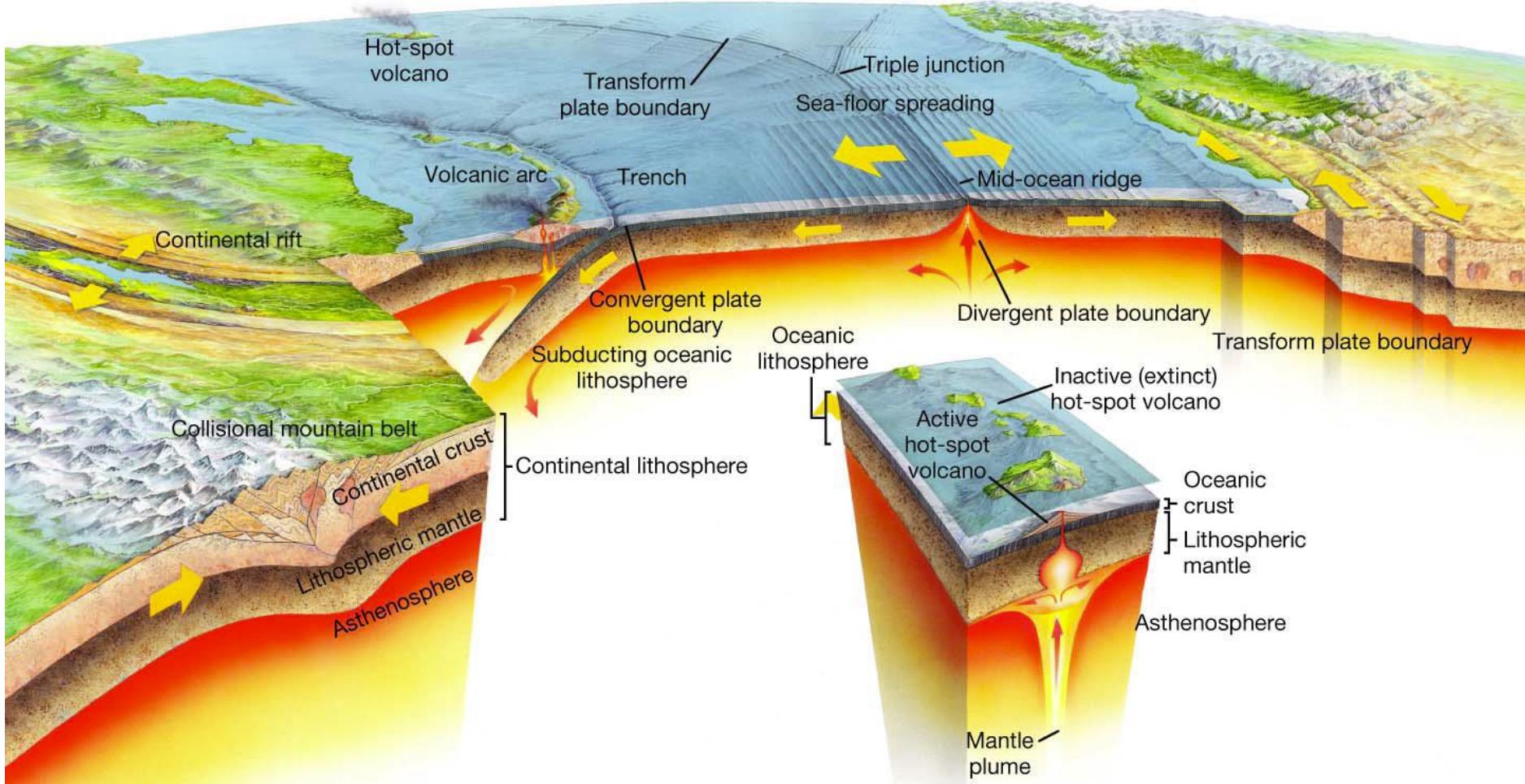
Cross bedding

Sand ball; Flame structure

Younging direction: bottom to the top



Deformation structures



The Theory of Plate Tectonics

Heat and gravity drive plate tectonics

Plate tectonics leads plate boundaries and interiors to deform to produce structures [fingerprint of deformation]

Brittle deformation structure

Joints

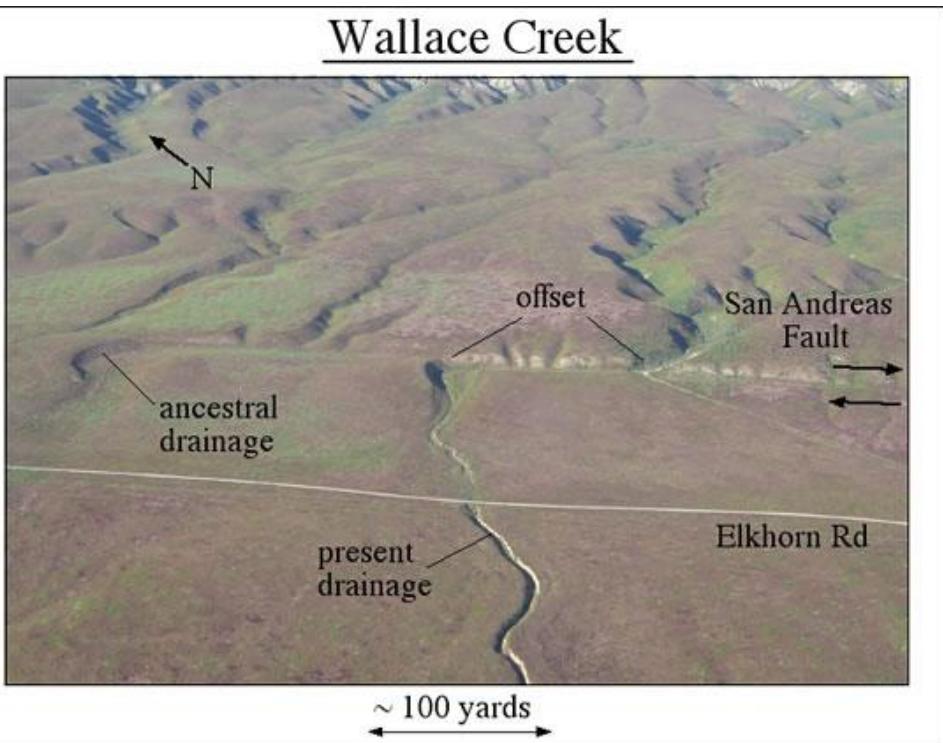
Fracture without noticeable movement along fracture plane



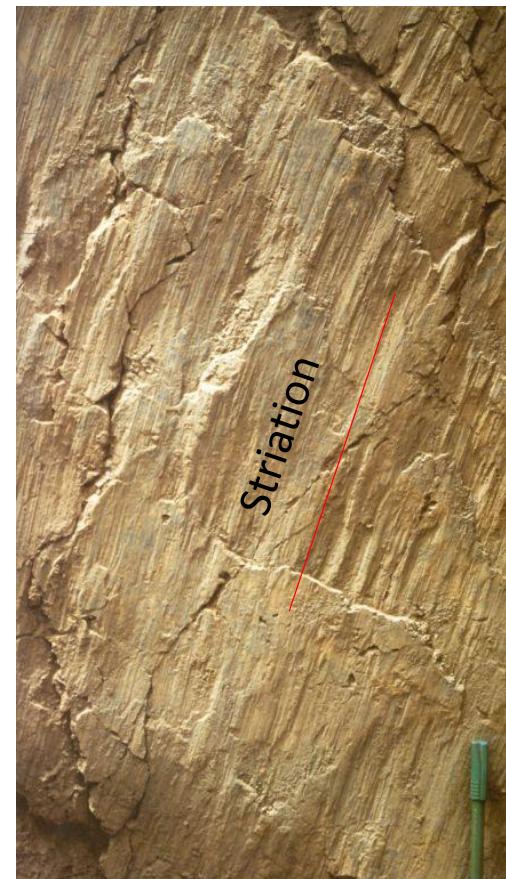
Courtesy of Jiang

Zhangjiajie, Hunan, China
Photo by Softdiyer

Brittle deformation structure: fault

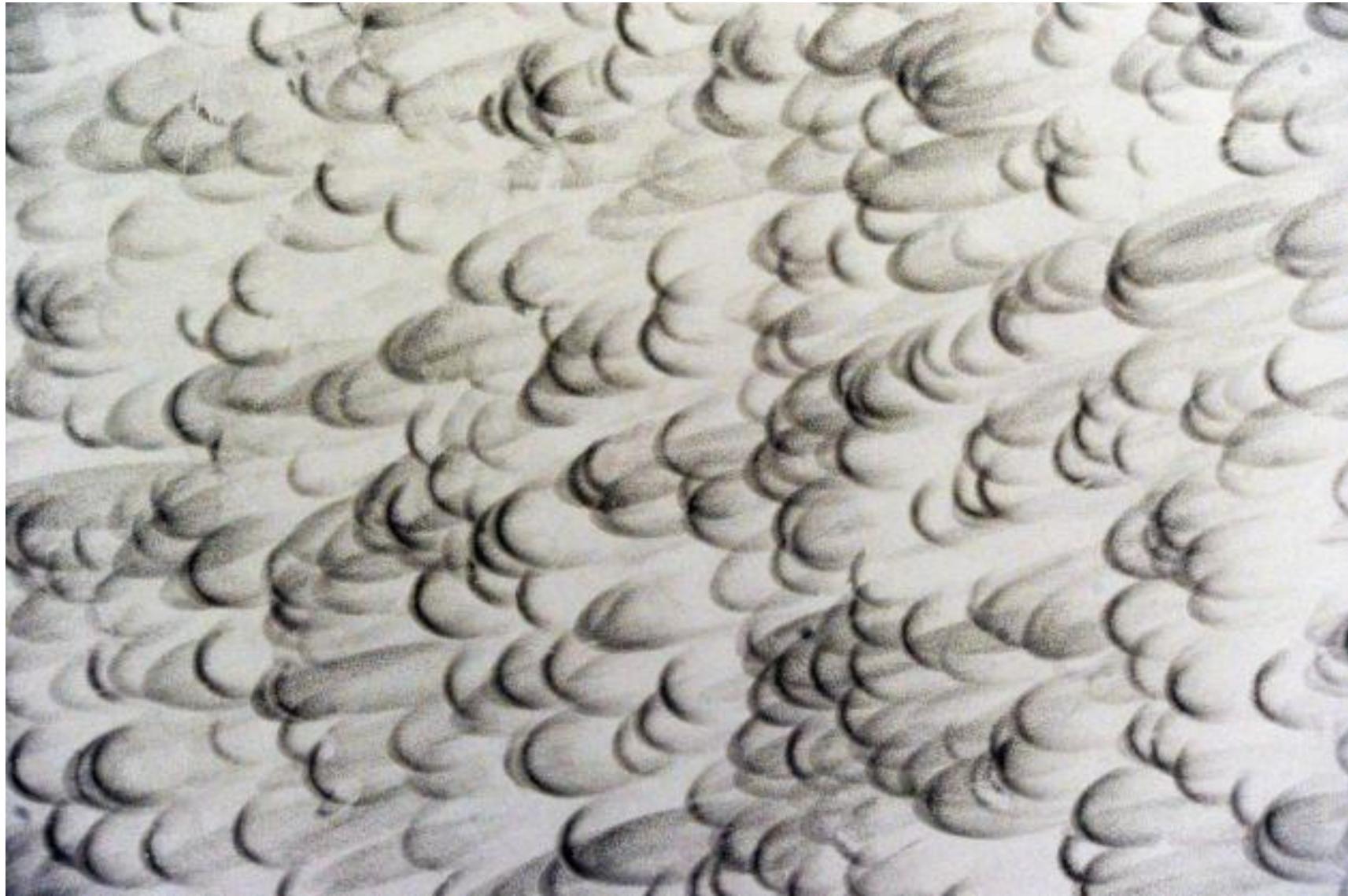


Aerial photo taken by David Lynch
<http://geology.com/articles/san-andreas-fault.shtml>



<http://blog.sciencenet.cn/blog-51597-550821.html>

Striation on fault plane



Squash ball marks left on the wall of a squash court at Greenwich Academy.

<http://www.greenwichtime.com/sports/article/Greenwich-Academy-squash-sweeps-Taft-4180873.php#photo-4007623>

Brittle deformation structures



Archean gneiss

In Sudbury

Breccia and pseudotachylite

Ductile deformation: rock flows



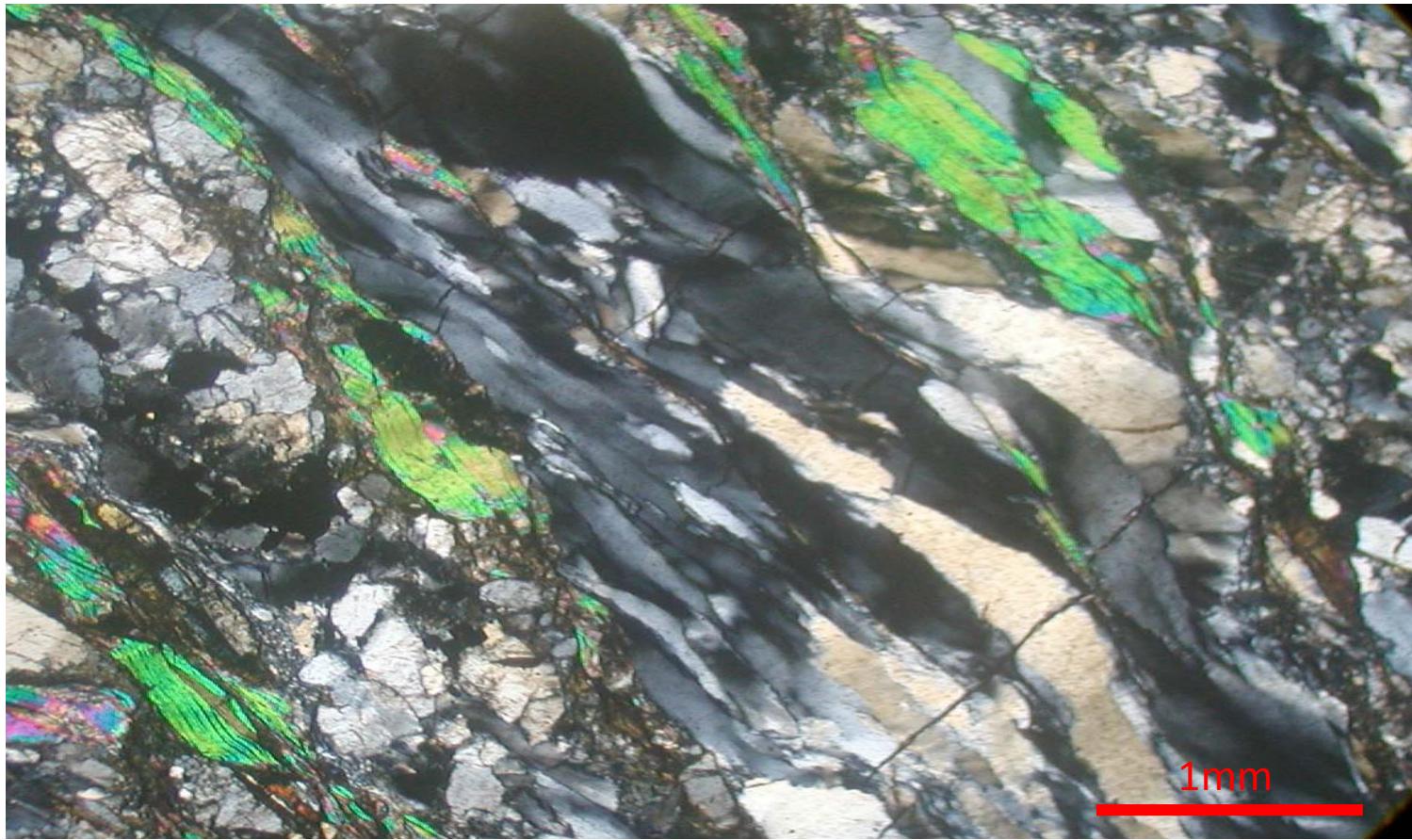
Silicone putty



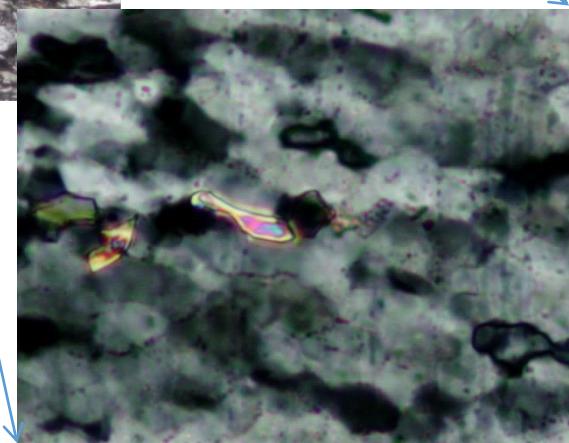
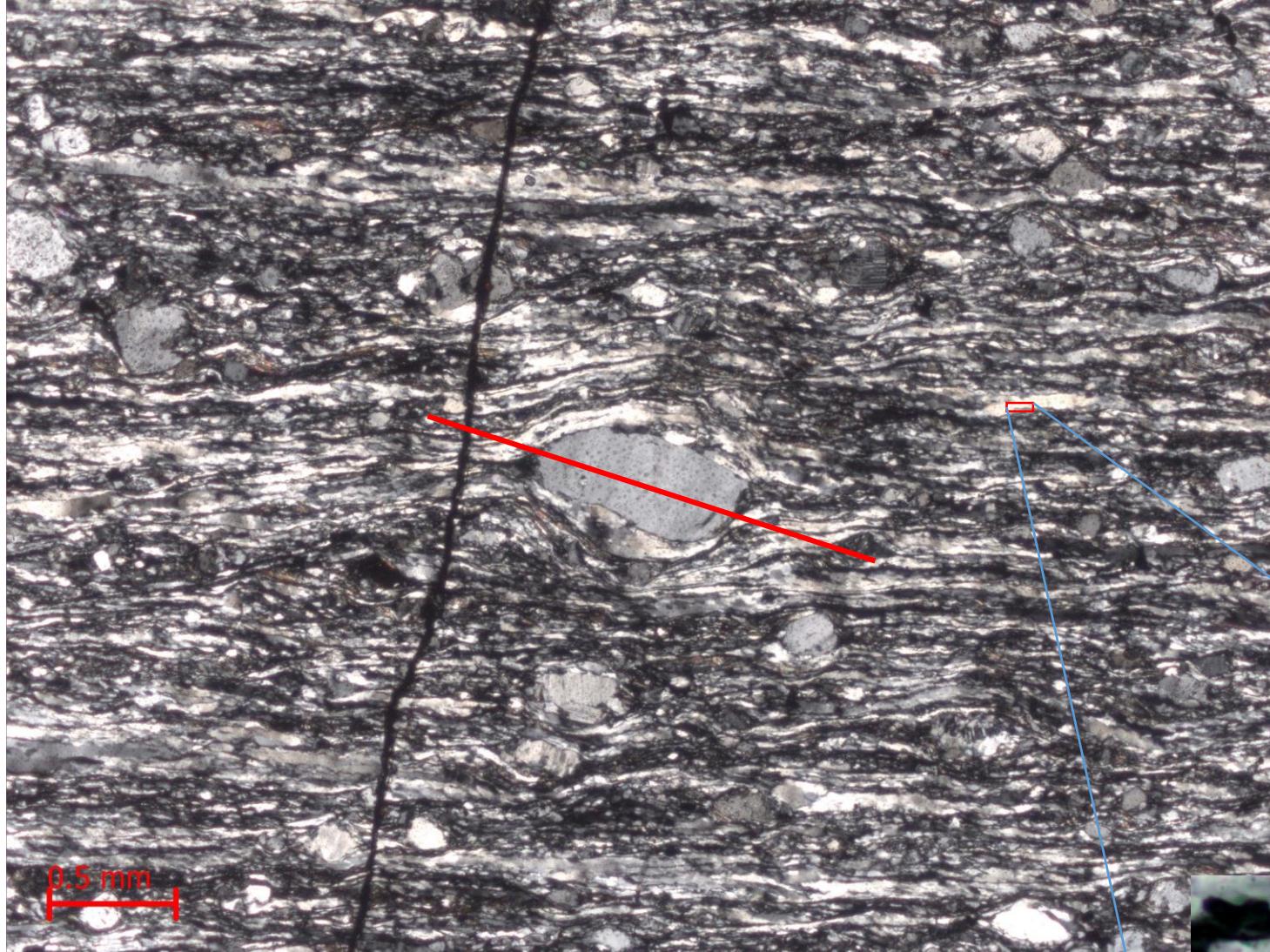
Are they breccias?

<http://blog.scienonet.cn/blog-51597-550821.html>

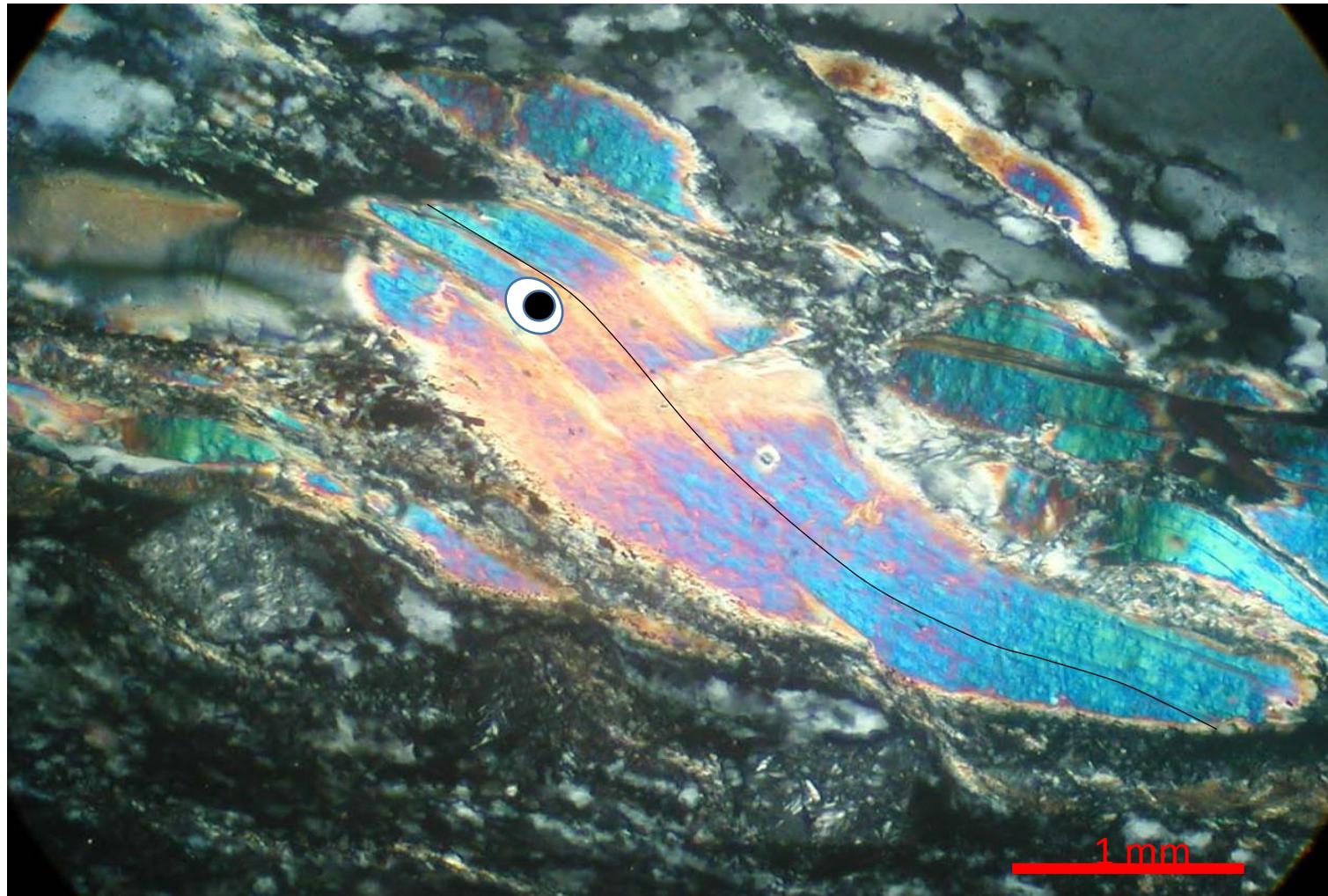
Ductile deformation: Quartz ribbon



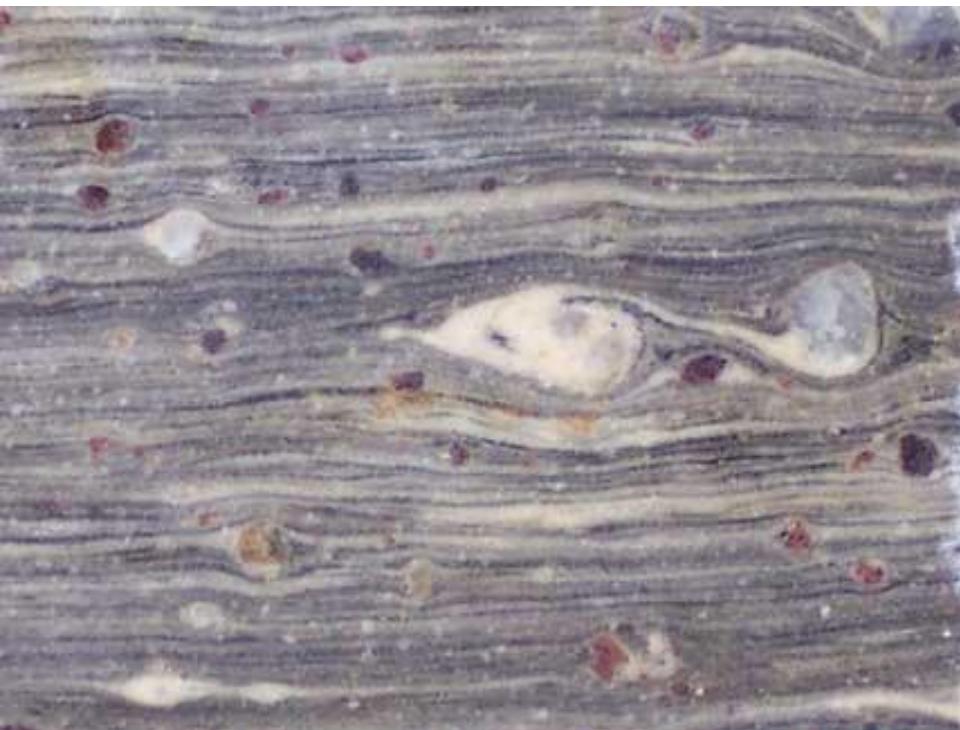
Grenville Front near Sudbury
Under microscope: quartz is stretched



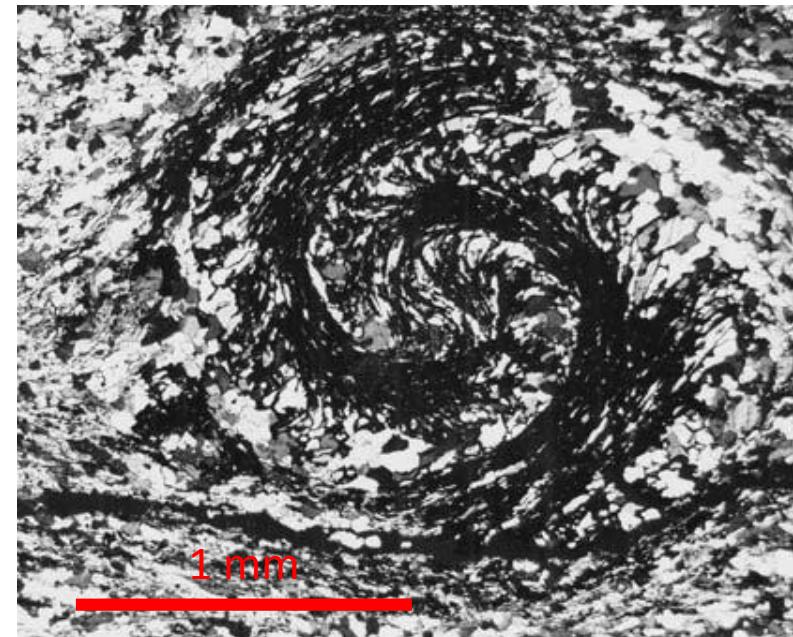
Ductile deformation: Mica fish



Snowball garnet

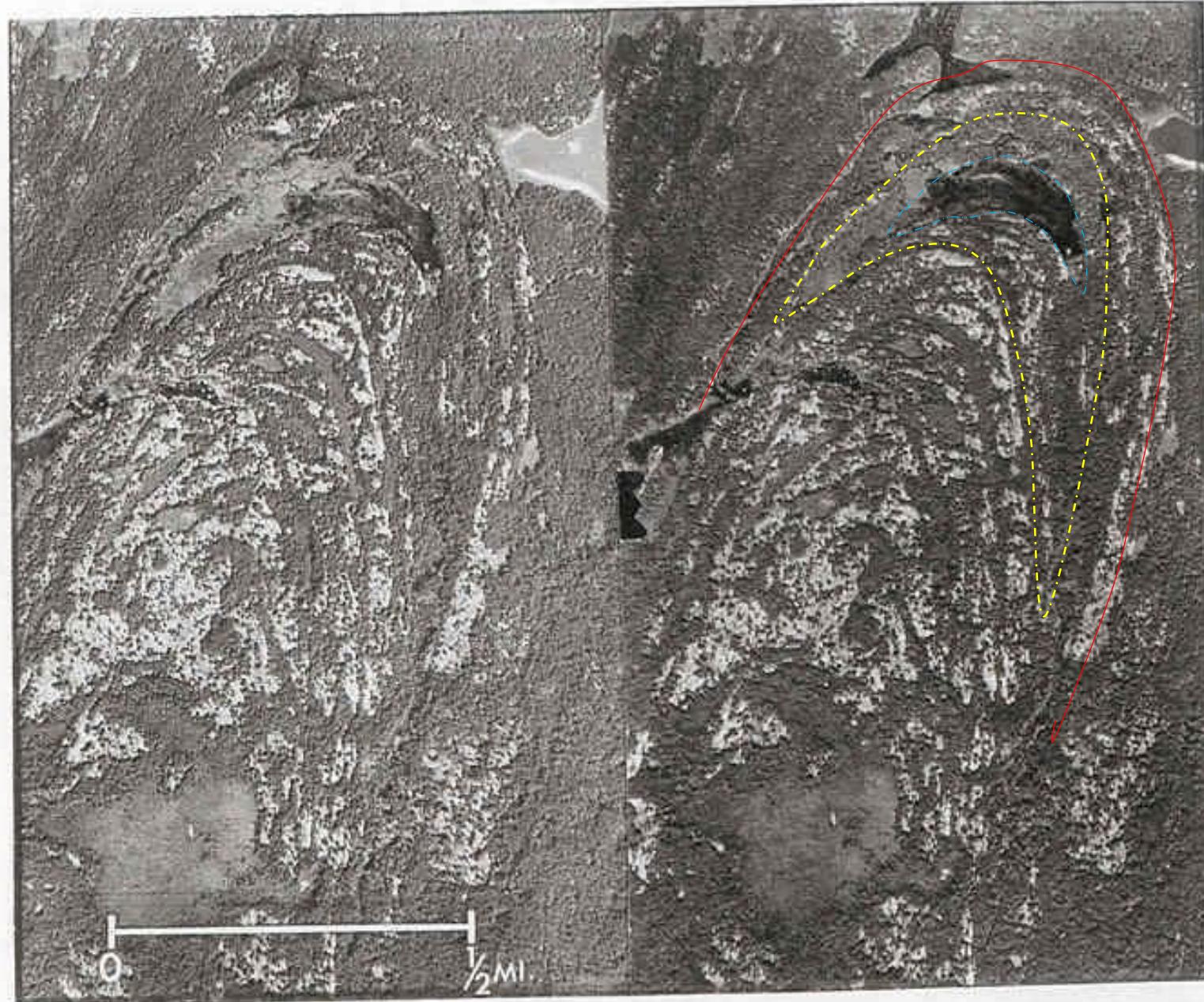


From internet



From internet

Spiral inclusion trail: Does the garnet rotate?
Clockwise rotation or anticlockwise rotation?
Why does it rotate?



Southeast of Haultain, Ontario. (From Gartner, 2004)

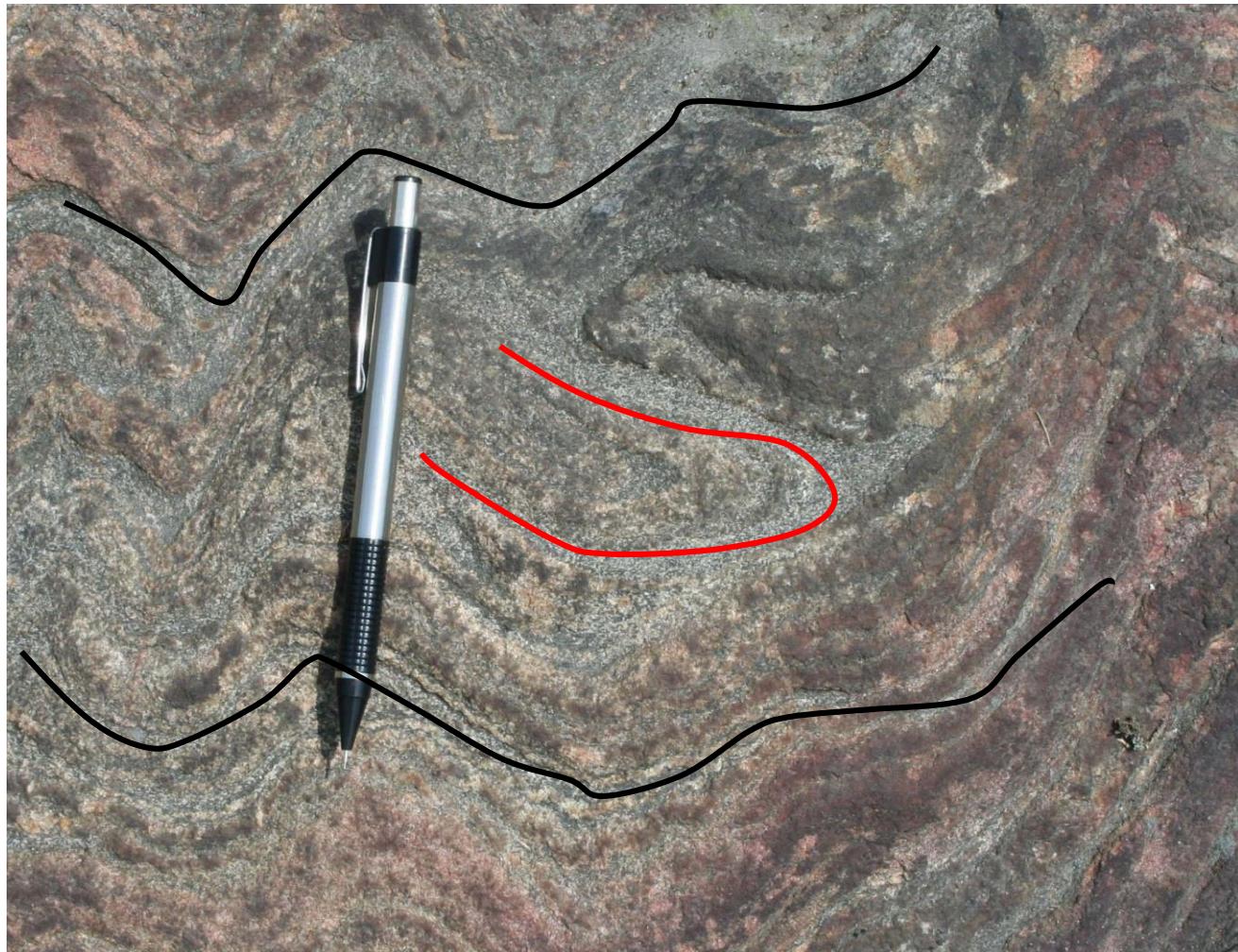


Ductile deformation: Folds



Folds near Sudbury, Ontario, in the Grenville geological province.

Ductile deformation: Folds



Near Sudbury, in the Grenville geological province

Ductile deformation: Transposition Foliation



Near Sudbury in the Grenville geological province

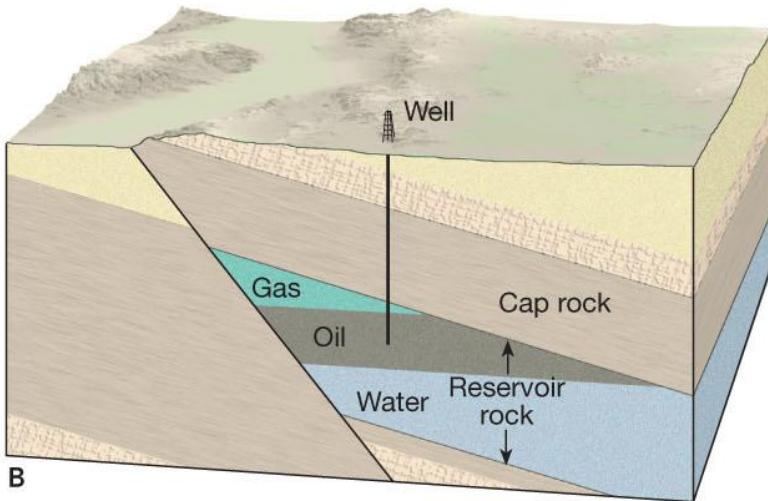
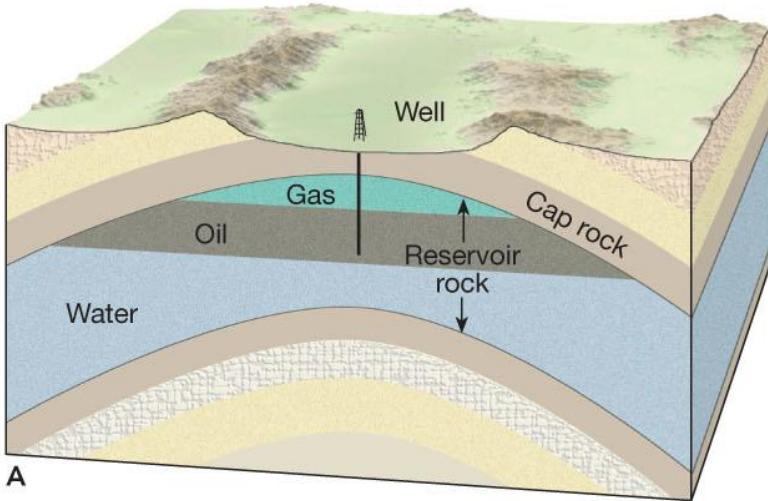
Purposes of Structural Study

- To understand Earth history (the tectonic history of a region)
- To understand the mechanical properties of the crust at the time of deformation
- To serve some more practical purposes such as mining, exploration, evaluation of slope stability...

3 Levels of Structural Study

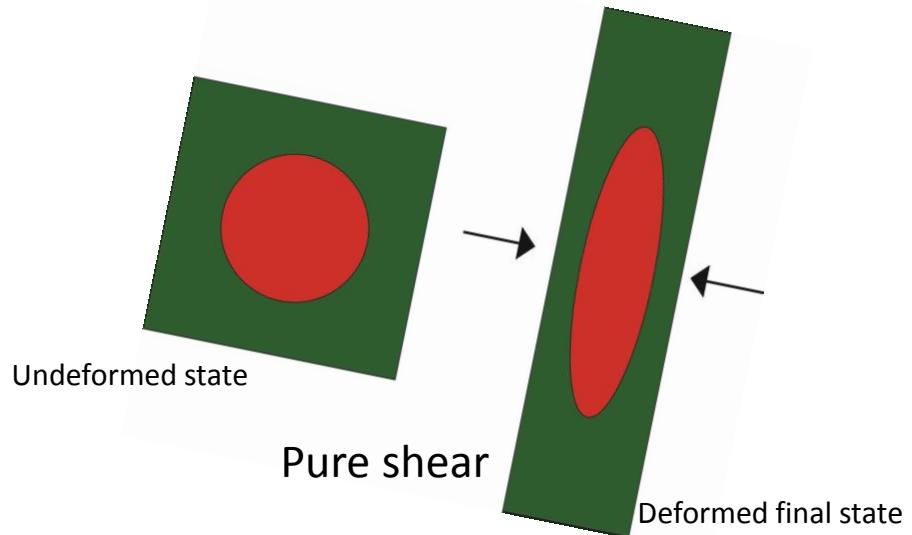
- Geometrical: descriptive; what is there?
Orientation, Size, Geometrical characteristics,
Relationship between structures
- Kinematic: Evolution of the geometry. Movement involved in producing the structures.
- Dynamic: The cause of the movement,
application of mechanical principles.

Why is geometrical study important?



- Resources exploration and mining
- Infrastructure construction
- Management of environment, mitigation of nature hazards
- Necessary for kinematic study and dynamic study

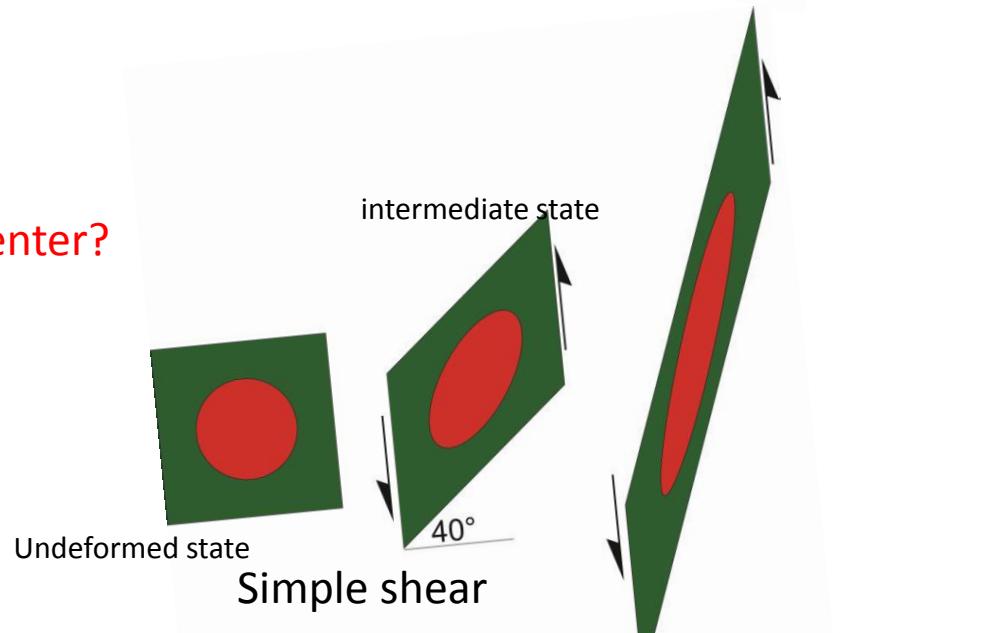
Kinematic study: Deformation process



<http://blog.sciencecn.com/blog-51597-550821.html>

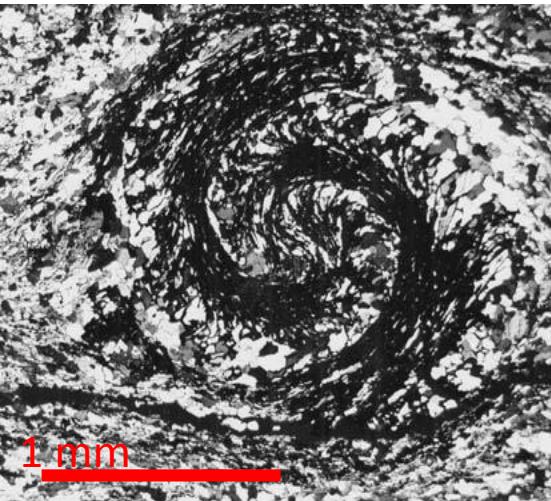
Squeeze from two sides toward the center?

Look for intermediate state

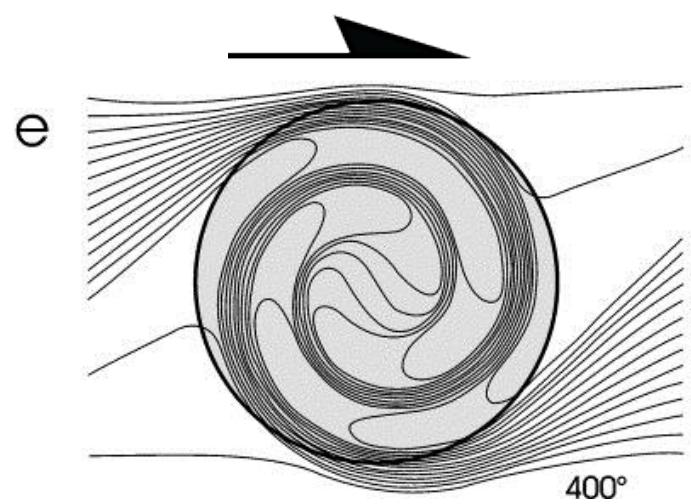
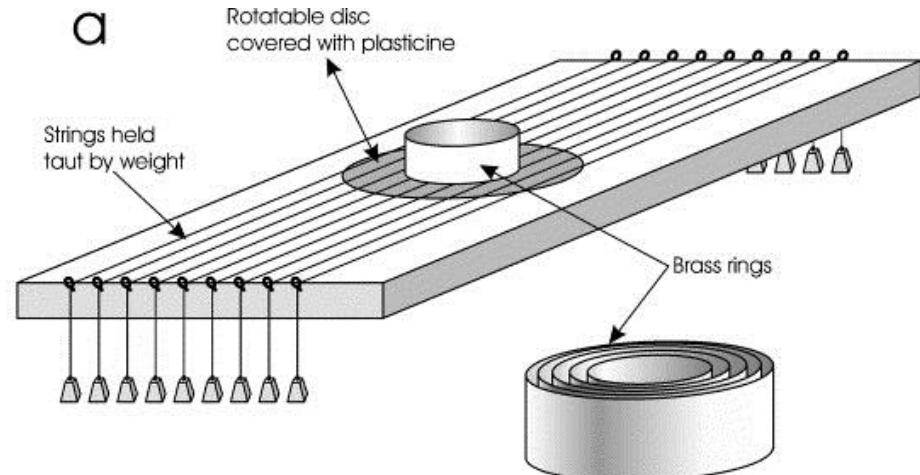
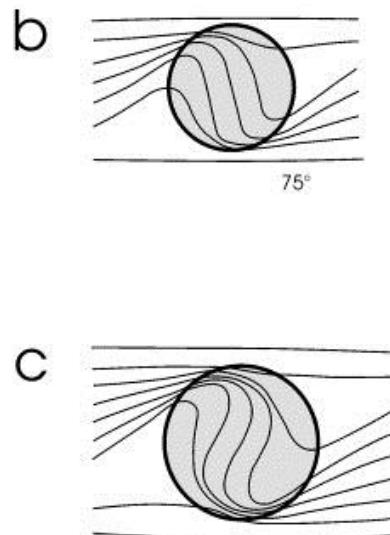
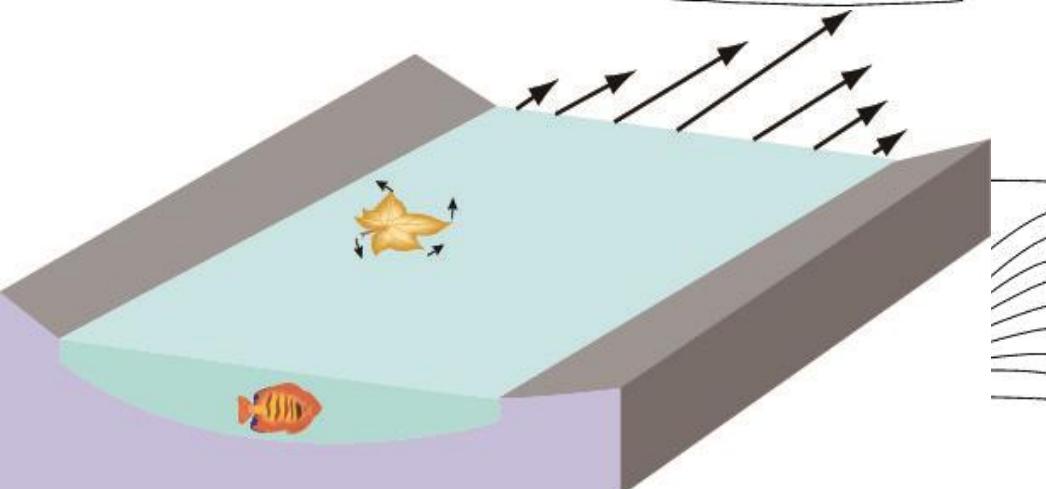


Deformation process

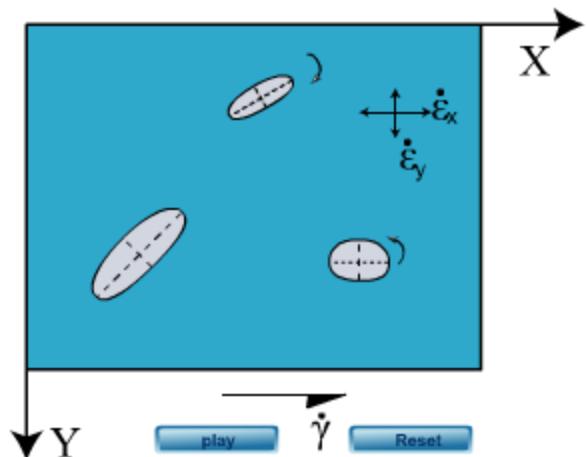
Snowball garnet

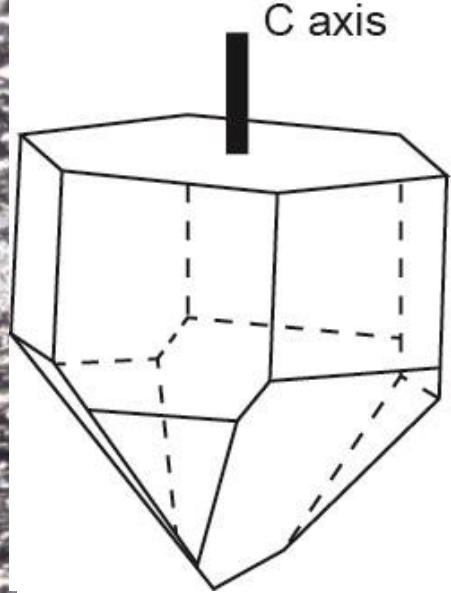
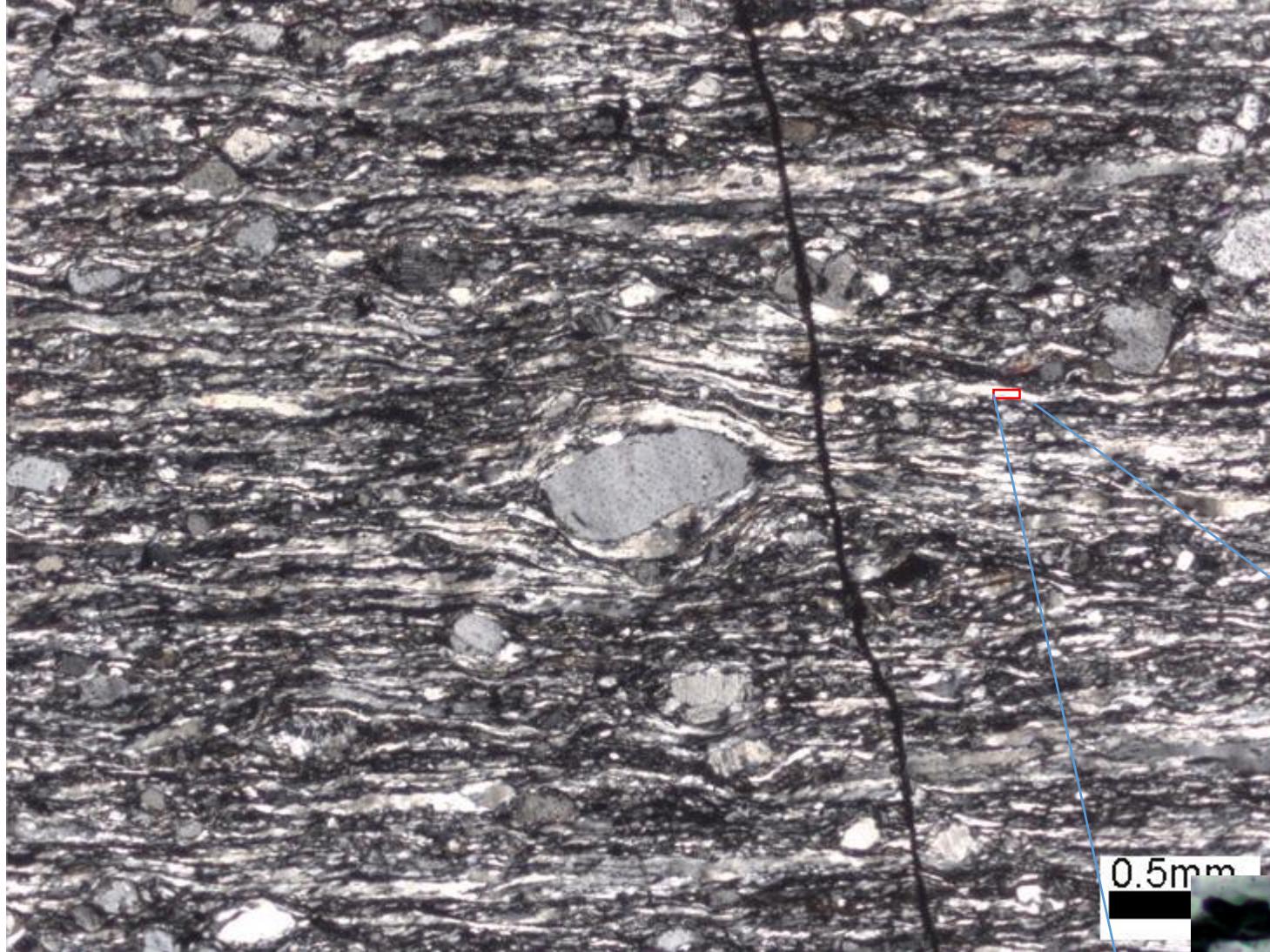


From internet

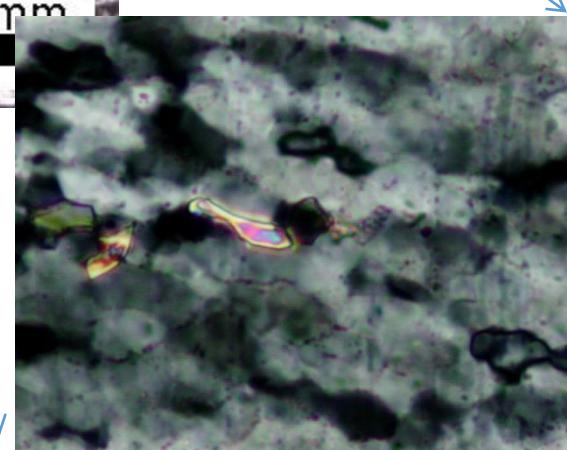


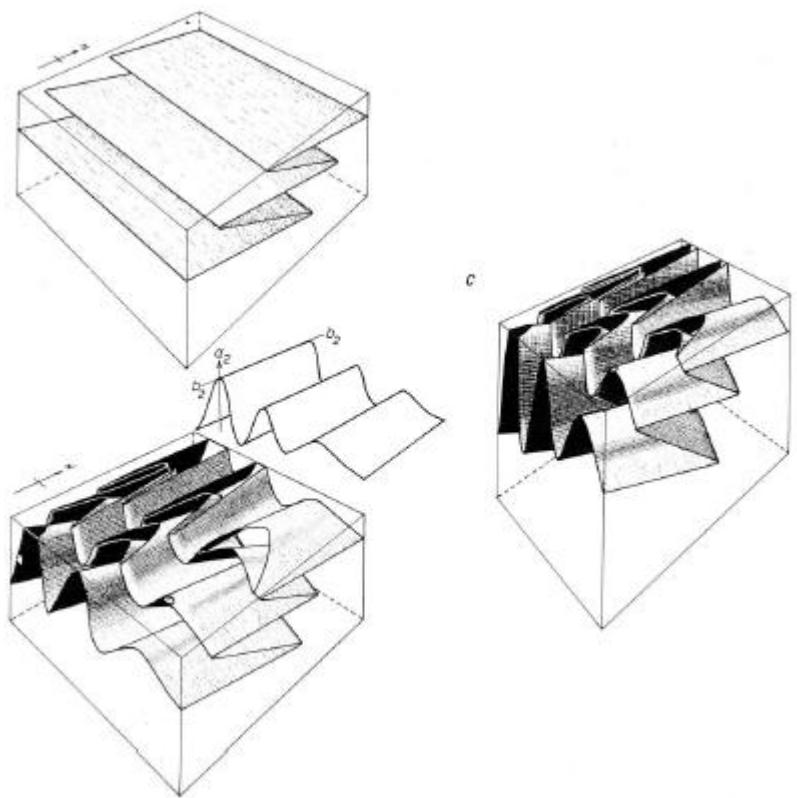
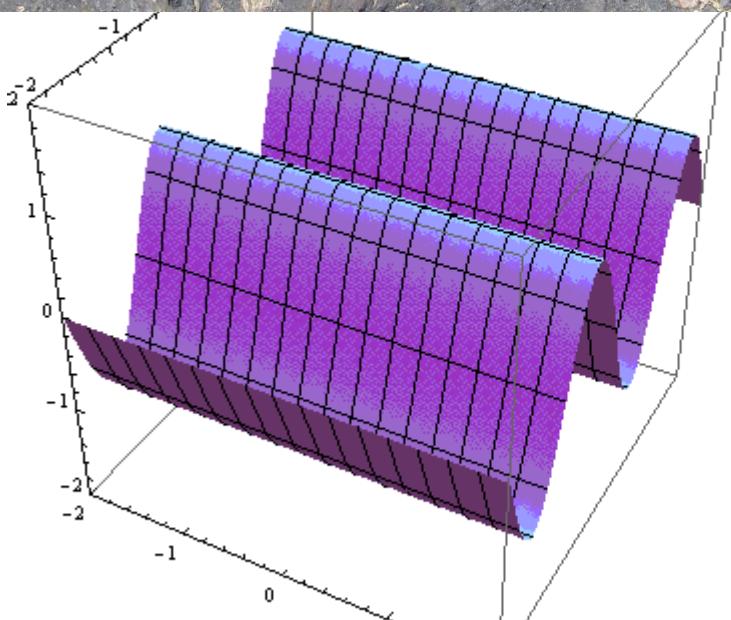
Jiang and Williams (1999)



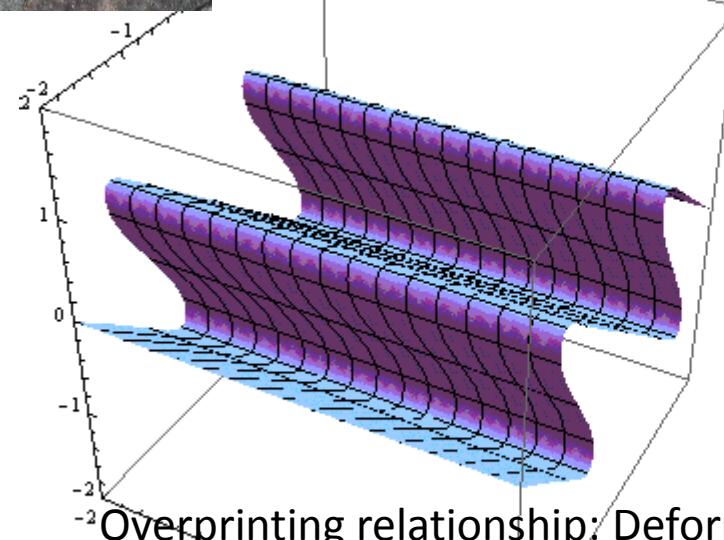
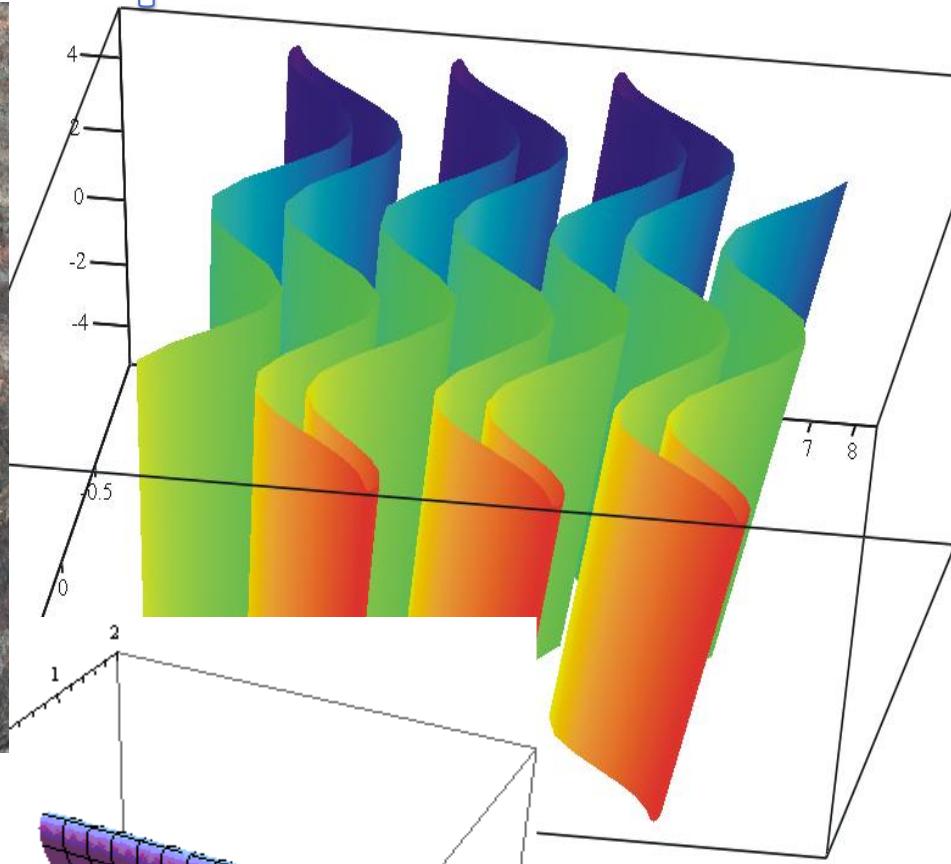
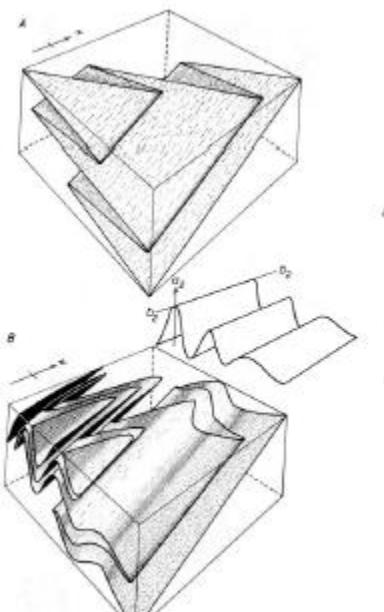
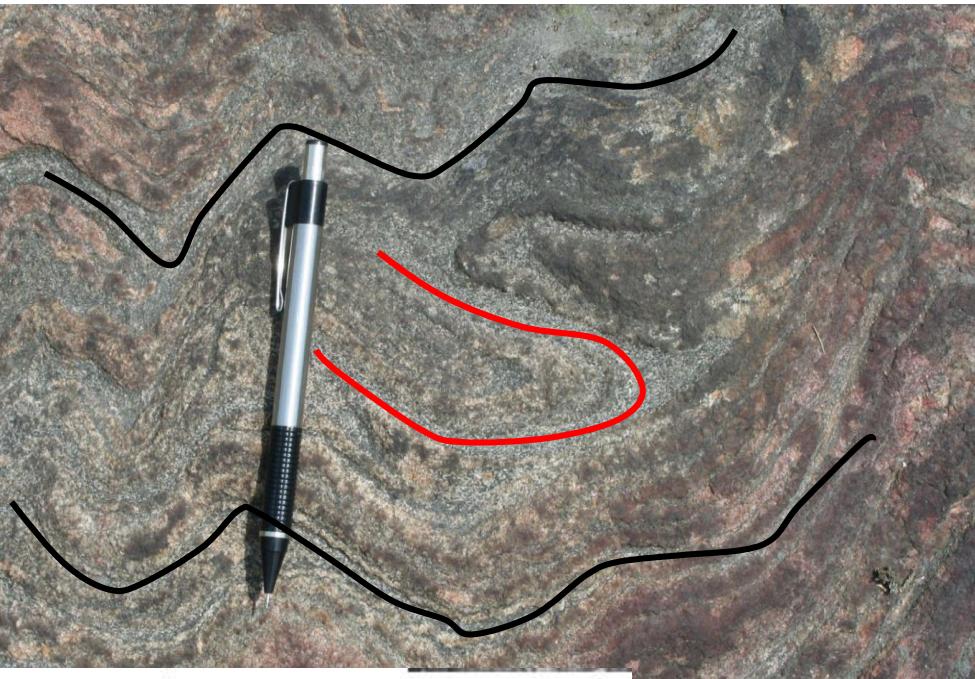


C axis: crystal
axis; optic axis

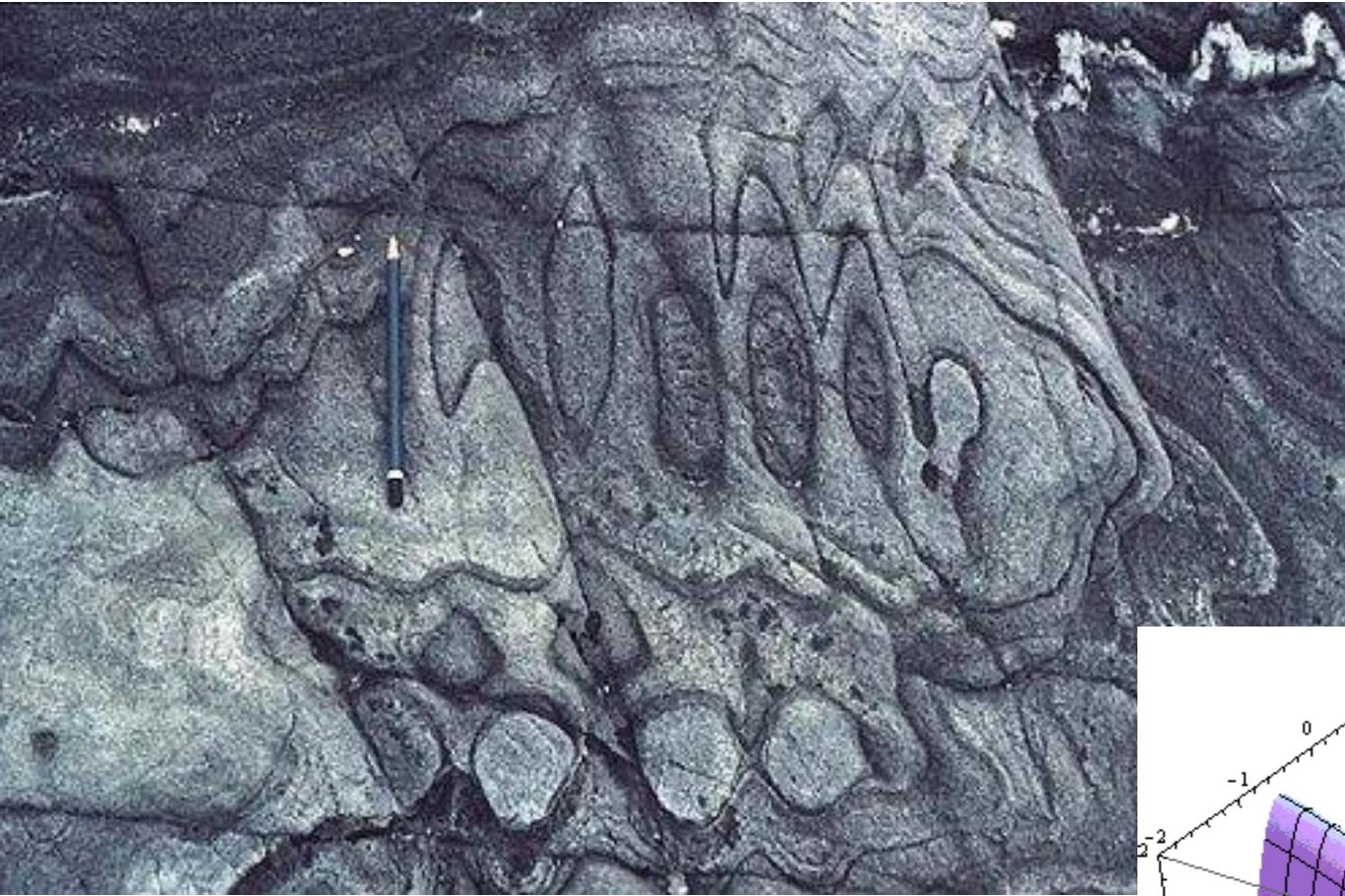




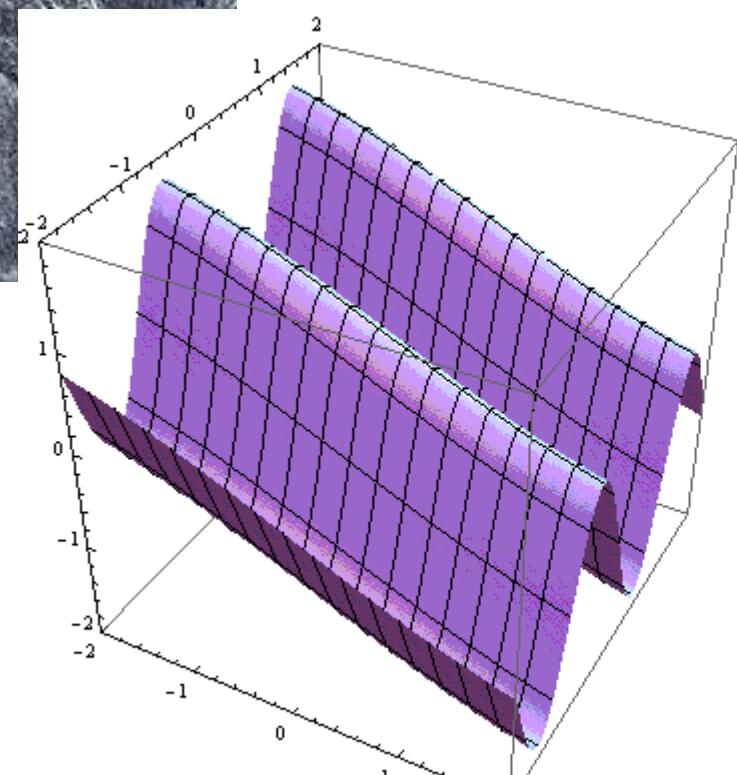
Deformation process



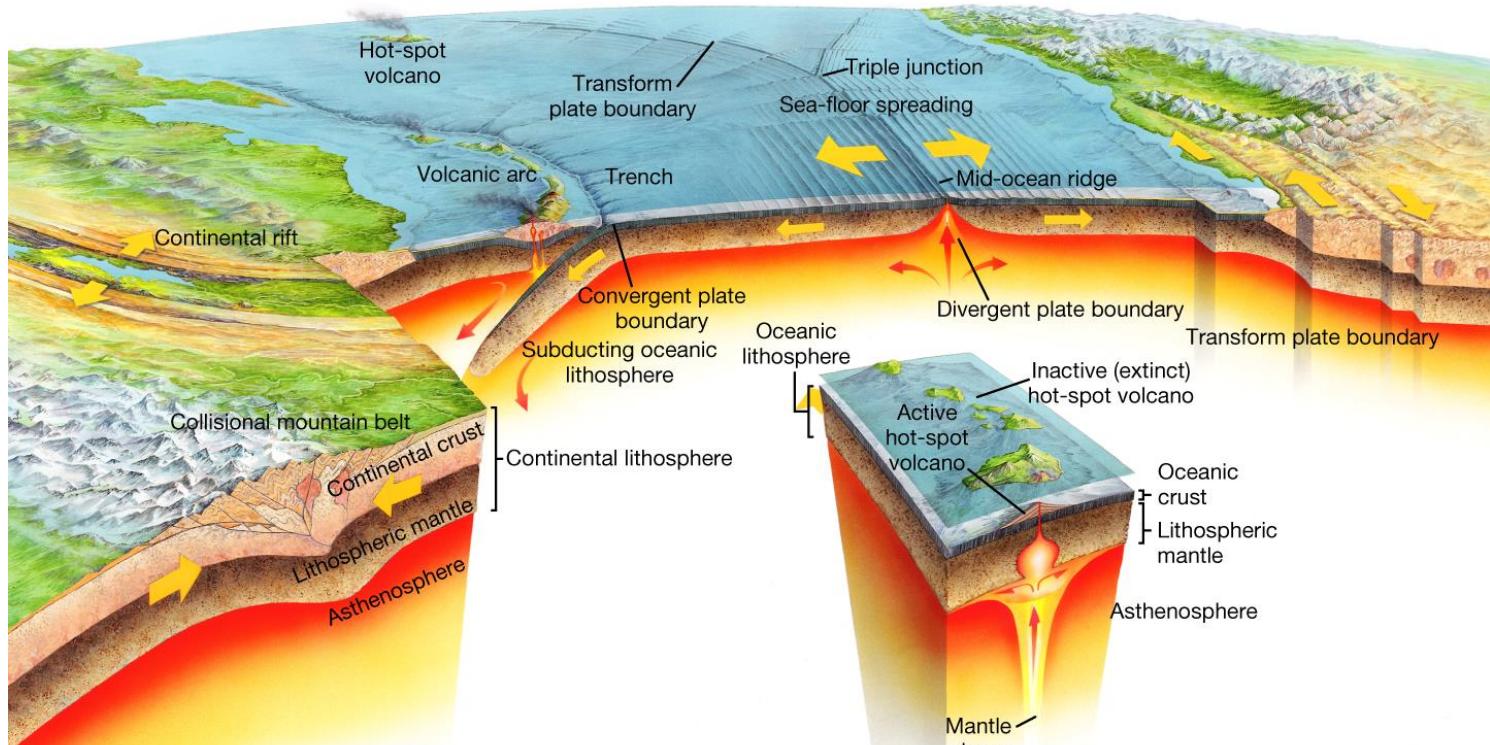
Overprinting relationship: Deformation sequences



<http://www.see.leeds.ac.uk/structure/folds/polyphe/ramsay1.htm>



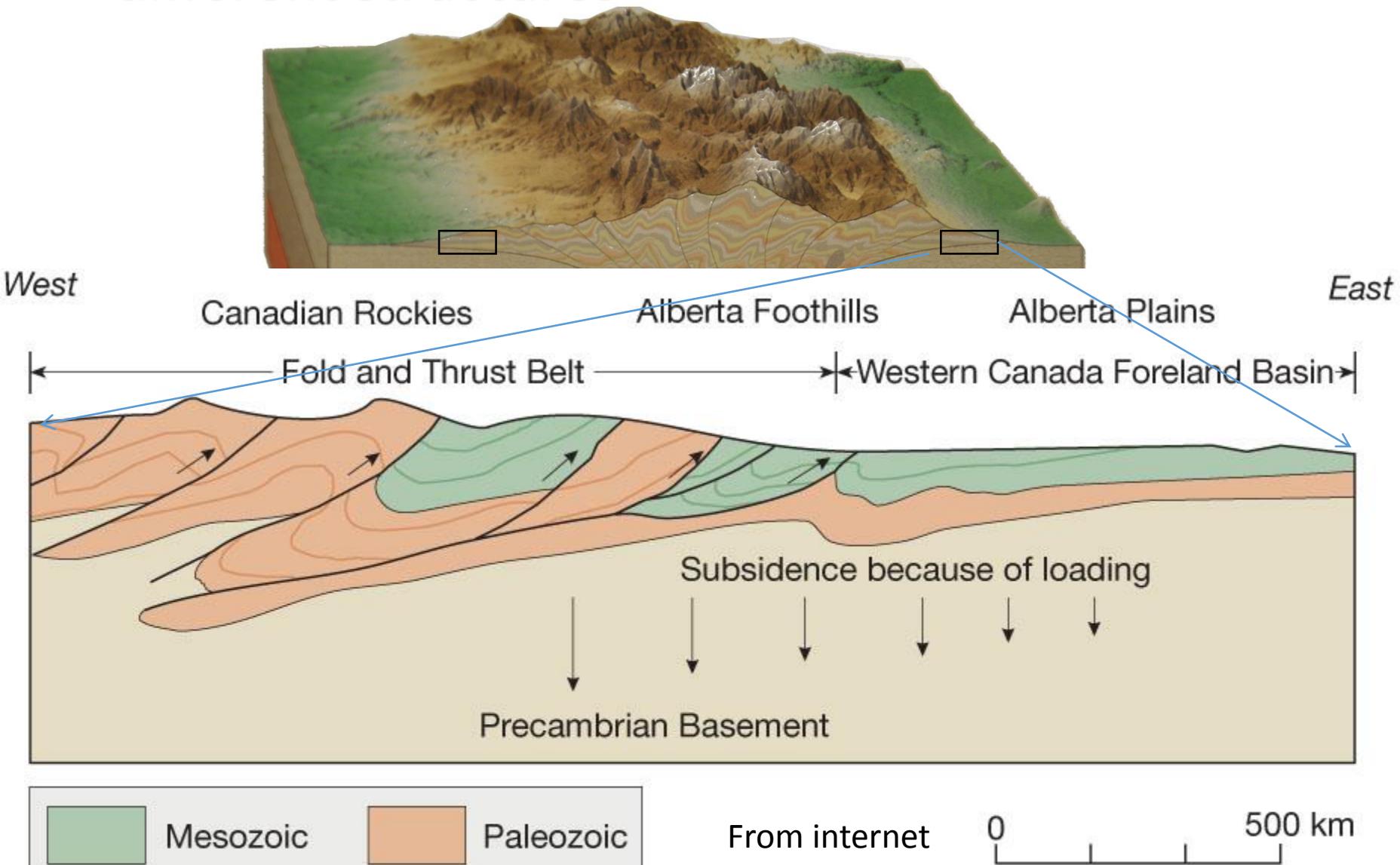
Deformation structures: fingerprint of plate tectonic movement



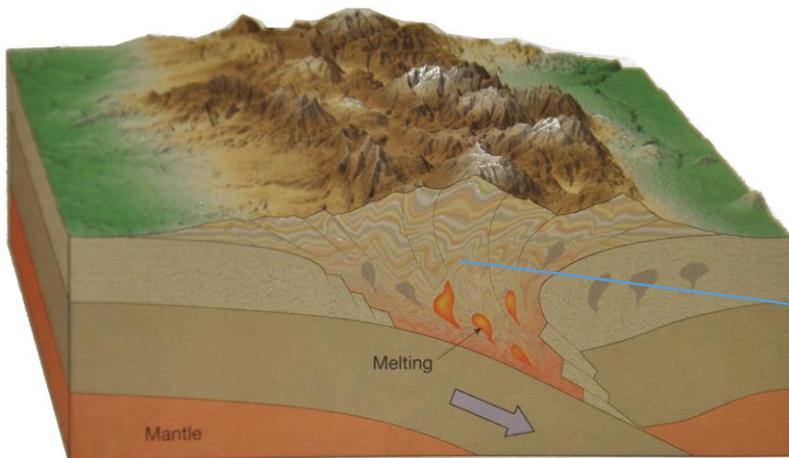
The Theory of Plate Tectonics

Plate tectonics causes plate boundaries and interiors to deform to produce structures [fingerprint of deformation]

Different tectonic deformation associated with different structures



Different tectonic deformation associated with different structures



Fold nappe

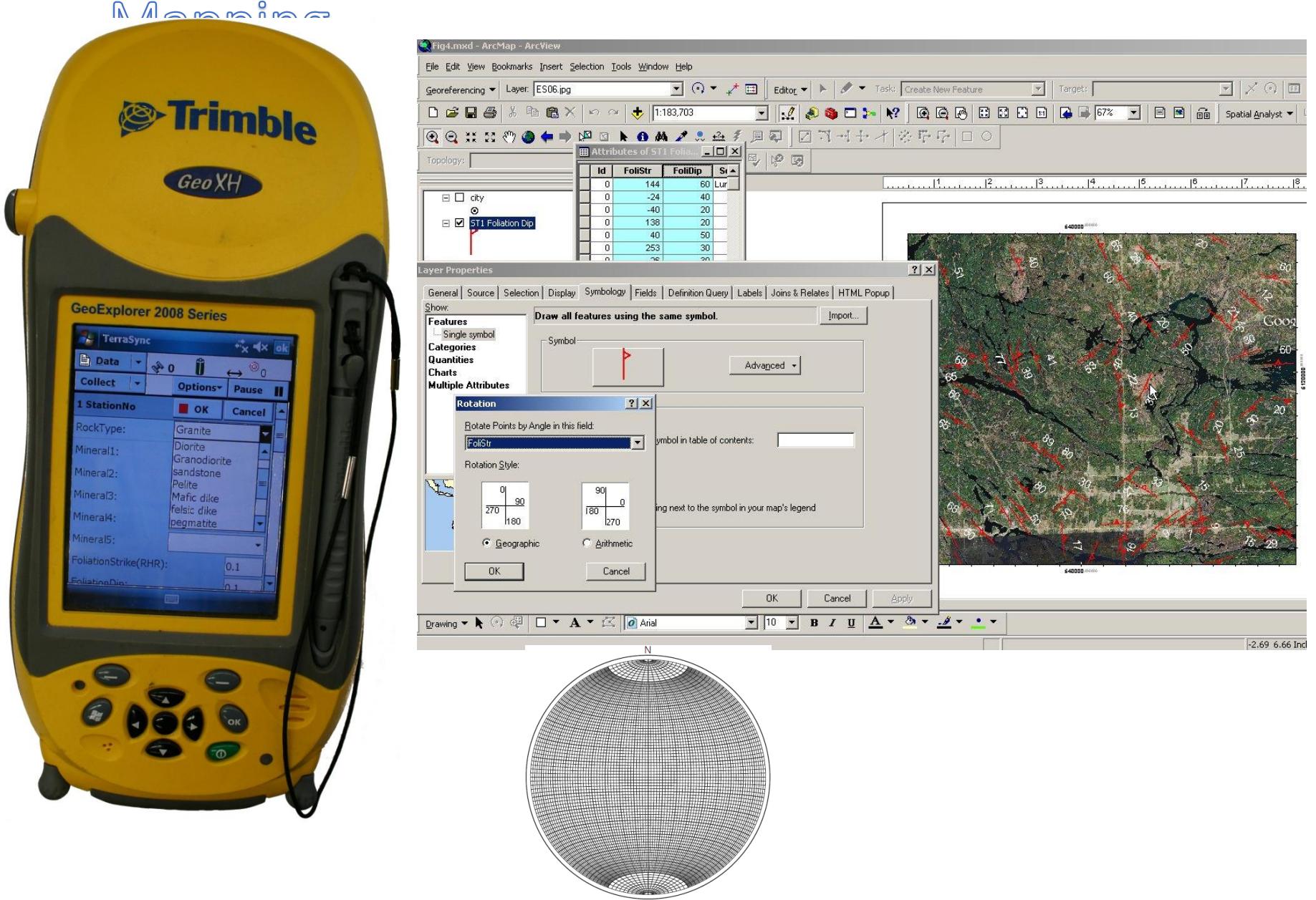
Parallel limbs

Geometrical study: most important



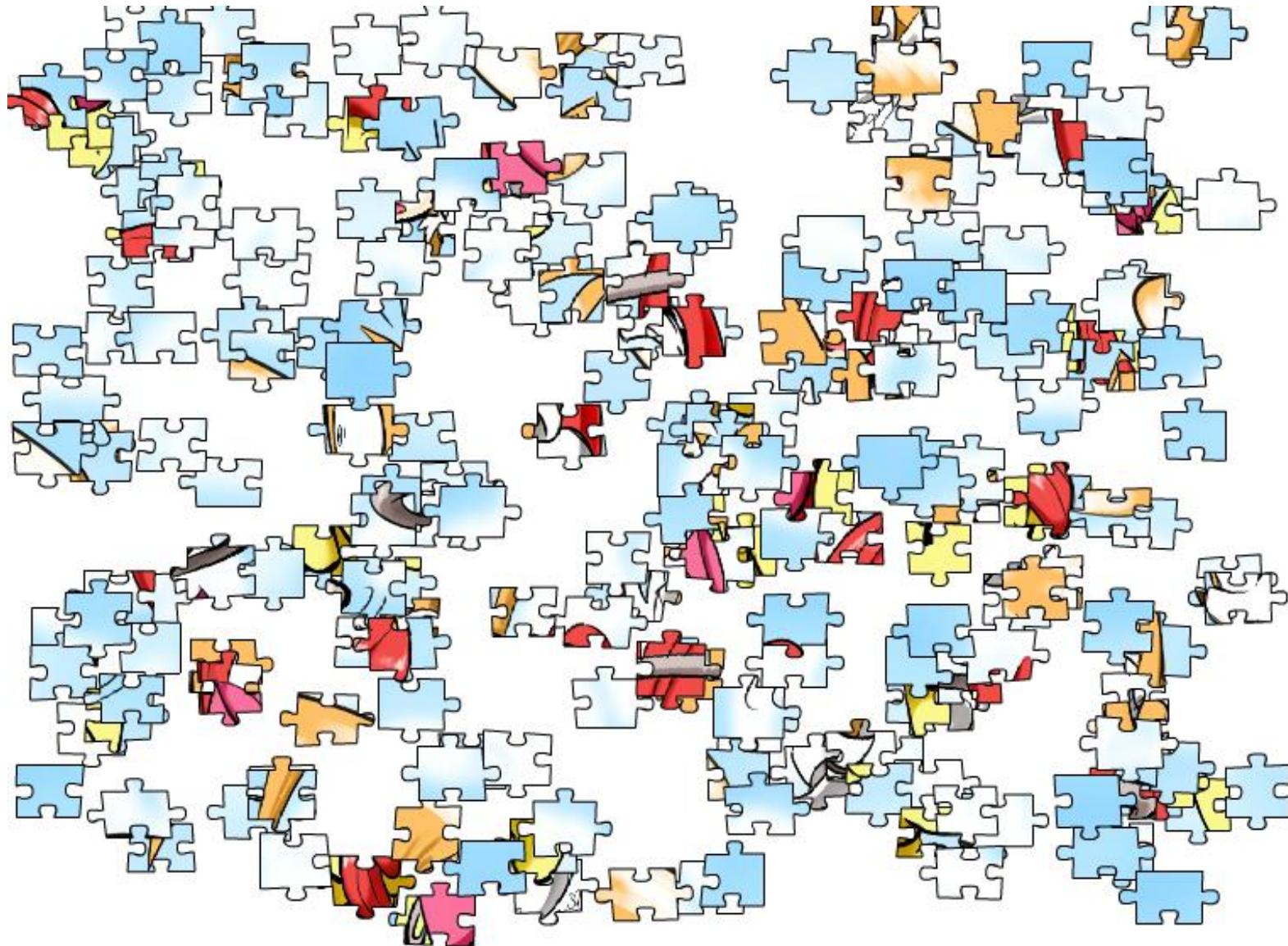
Sheep Mountain in the U.S.





Incomplete jigsaw puzzle

Mapping is interpretation









Field observation at outcrops

- Orientation
- Overprinting
- Distribution



Geometry In 3D for whole area:

- Orientation
- Overprinting
- Distribution



- History?
- Tectonic evolution?

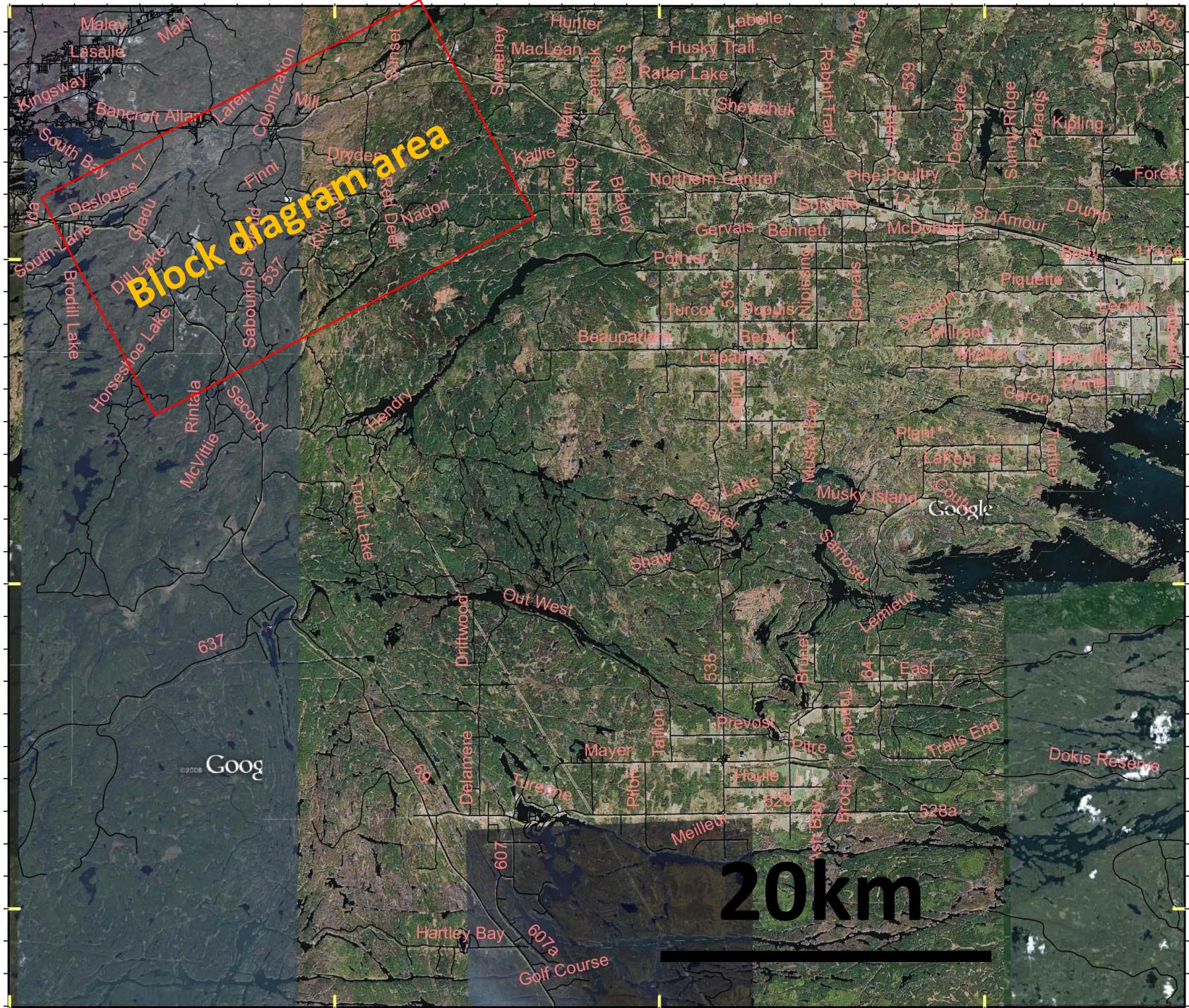
- Numerical modeling

Two questions to think about

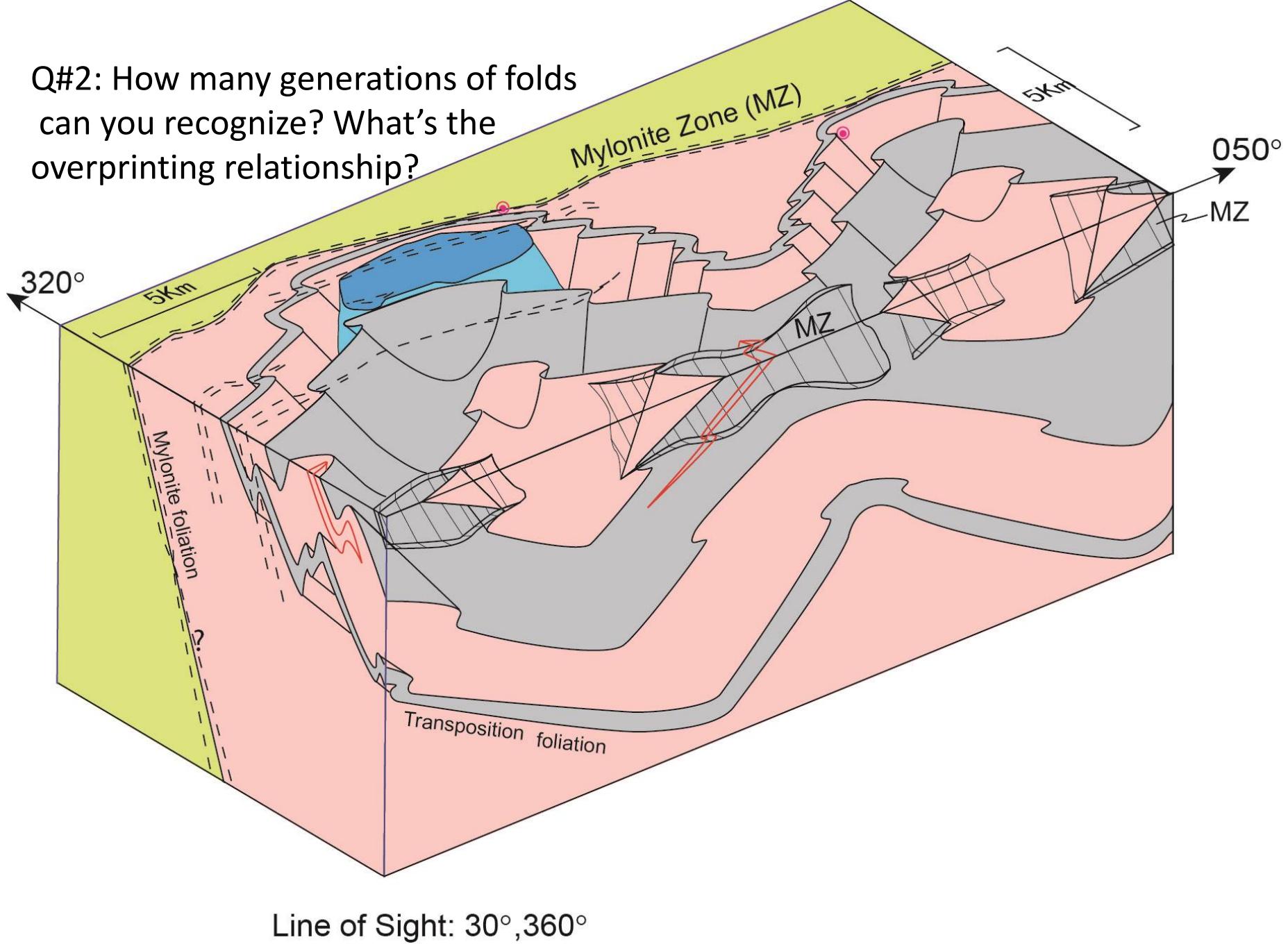
Q#1: What are the linear structures?



Q#2



Q#2: How many generations of folds can you recognize? What's the overprinting relationship?



Next lecture

Some practical application examples:

- Geological data interpretation in mapping
- From geometrical study to kinematic study to tectonic model